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ON THE SPATIAL STRUCTURE OF THE SOLAR CORONA

by

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ON THE SPATIAL STRUCTURE OF THE SOLAR CORONA

(O prostranstvennom stroyenii solnechnoy korony)

PART I

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A B S T R A C T

This paper deals with some general problems related to the study of the spatial structure of the solar corona. Particular emphasis is given to the problems one way or another connected with the corpuscular streams.

The first section deals with the relationships between quiescent prominences — filaments and coronal streamers.

Section two is devoted to discussions of the law governing the structure of the solar corona. Special consideration is given here to the "intermediate-type" corona, characterized by a decreased brightness in the low latitude belt, and an increased brightness in the mid-latitude belts. The former includes those of active regions, and the latter — the streamers' belt. Two hypotheses are considered for the explanation of the low latitude belt. In the

first hypothesis these properties are determined by such large-scale solar characteristics as the general magnetic field of the Sun, its rotation, etc. In the second hypothesis the above properties are determined by the fact that active regions deflect the corspuscules originating through the continuous ejection of solar gases from the Sun (solar wind), thus creating above them empty cavities. It is shown that the latter hypothesis meets with serious difficulties.

In the third section, the main geometrical properties of the streamers are discussed. Special attention is given streamers' extension. Many arguments are given which attest to the fact that their length is of the order of 30 to 50 solar radii ($30 - 50_{\odot}$). Assuming that they extend to the terrestrial orbit, they do so in a very attenuated form. In no case can the streamers by the source of M-disturbances.

The discussion of the Waldemeier paper [26] upholds the fact that its conclusions encounter serious difficulties.

The next part of this work (Astronomicheskiy Zhurnal, No.4, 1962) will consider the coronal rays above the active regions, and the results of optical (eclipse) observations will be brought into agreement with radioastronomical and polarimetric data.

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1. Up to the present time our knowledge of the structure of the solar corona was mainly based upon the study of photographs

obtained during solar eclipses. However, the possibilities of such a method are very limited, mainly because during the total phase of the eclipse we are in the position to register only a certain aggregate result of the projecting of the whole solar corona (as a transparent formation) on the pictorial plane. Besides, it is quite clear, that even such arbitrary hypotheses as that of corona's spherical symmetry and others are very remote from the reality. In other words, one cannot obtain even a rough idea about the spatial configuration of the solar corona by mere studies of photographs of standard quality taken during eclipses. This assertion was upheld as a result of the last radioastronomical and polarimetric investigations having established that the corona is denser over active regions than above any other spots in the Sun. At the same time entirely opposite conclusions have been reached on the basis of optical eclipse observations.

Consequently, it is extremely important to compose a certain general picture of the spatial structure of the solar corona using the newest methods available and the latests results so obtained, and to coordinate optical eclipse observations with radioastronomical, polarimetric and other data. Our attention will then be drawn to questions related with the problems of corpuscular streams.

One of the most characteristic properties of the solar corona observed during eclipses, is its rays. Three fundamental forms of coronal rays may be outlined (see ref. [1] , p.93): short, bent rays above the undisturbed part of Sun's surface, more particularly in polar regions; b) rays above the active regions; c) the so-called "helmets", ending either in a single long ray, or as a fan of diverging jets. Quiescent prominences are usually situated at the base of helmets, as is observed in photographs of eclipses. For brevity, we shall designate the helmets together with their endings, either in the form of rays or of a single ray, as P- rays, bearing in mind the connection between the considered phenomena and the prominences. Similarly, we shall designa- the rays above the active regions as AR- rays.

Because P-rays are the most prominent formations in the solar corona, as it appears from the latter's photographs, and also on account of their link with the prominences, it is often considered that the general shape of the corona and its variation with the solar cycle phase, depend on solar activity by prominences, and namely on latitude at which they are found (see ref. [1], p.6). But in reality, this is more complex: A series of factors speak in favor of the idea that corona is of primary importance in the given problem, and namely its magnetic fields, while prominences are of secondary importance. This is for instance related to fact, that a new filament, of identical shape, appears quite often after a filament has been destroyed by a new active region or by a chromospheric flare. This filament appears at the place of the former, sometimes very quickly (see ref. [2] pp. 210, 230, 239). Furthermore, the process of disappearance and of "revival" at the same spot is observed several times. All this implies the existence of some sort of stable magnetic structure in the helmet region. Besides, lately it became obvious, that the most quiescent prominences are formed by way of condensation of coronal gases and not as a result of gas outflow from the chromosphere (see for example [2] , p. 245). Thus the most quiescent prominences (and filaments) are only indicators, pointing to the presence of a coronal helmet in the given region of the Sun. At the same time, it follows from the above considerations, that the very existence of the helmet does not necessarily imply the presence within it of a quiescent prominence, and that the quiesecnt prominence cannot occur without the presence at the given spot of coronal gases from which it condenses. In other words, there is basis to consider that whenever we observe a quiescent prominence, it must be confined inside the helmet. These conclusions follow in particular from eclipse observations which show that at times a somewhat powerful prominence-filament is absent at the base of the helmet. That is why the above consideration must be borne in mind during the morphological analysis of the general spatial characteristics of solar corona.

The discussion of the latter will be broken in a series of parts. We shall examine at the outset certain general questions, after which we shall discuss the radial structure of the corona. To conclude, we will analyze the question of coordination of optical eclipse observations with the radiosatronomical. polarimetric and others.

2. We shall discuss in this part certain general laws governing the structure of the solar corona. stemming from the examination of photos.

We shall begin with the "intermediate-type" corona (see the well known drawings by A. Ganskiy and V. Lok'yer on page 150 of reference 1). Although quite schematic, these drawings point to the fact that the corona appears in the eclipse photographs as being significantly less intense and stretched in the near-equatorial or near-polar regions than in the "mid-latitude" regions of the Sun, where P-rays play the main part.

Two different hypotheses may be proposed for the explanation of these properties of the "intermediate-type" corona:

a) In the first hypothesis it is estimated that the presence of relatively intense mid-latitude regions with P-rays, and also that of substantially less developed near-equatorial and near-polar regions of the intermediate corona, reflects such "large-scale" characteristics of the Sun as are its total magnetic field and the distribution of the latter about its surface (for a given solar cycle phase), and the laws governing the rotation of the Sun etc. The part played by the active regions of the Sun is considered as secondary in this hypothesis. Within the framework of the considered hypothesis, the mean density of the corona in the near-equatorial belt (between active regions) is lesser than that in the belt of P-rays' disposition. This results in the decreased brightness of the corona in the near-equatorial belt. (Speaking of the near-equatorial belt, we have in mind the whole latitude region bordered at both sides of the equator by the lower bases of P-rays). In that case, the active regions cannot change the considered brightness correlations (see part 6 of this paper).

b) From the point of view of the second hypothesis [3], [4], the decreased brightness of the corona in the near-equatorial region is explained as follows. It is assumed that in all those spots of the corona, where active regions are absent, there takes place a continuous gas outflow from the Sun with a power practically independent from the spot's latitude. As to the active regions, their part consists in that each of them deflects laterally the corpuscules of the above-indicated outflow of coronal gases from the Sun, "solar wind" - creating above itself a certain relatively empty cavity in the form of a cone, designated as "cone of evasion". This relative "emptiness" is precisely the cause of lowered brightness of the corona in the near-equatorial belt each time there is one or several active regions near the limb of the Sun. (see the respective figures 5 and 6 of ref. [4]). Therefore, from the standpoint of the given hypothesis, the density of the corona in the near-equatorial belt (between the active region and outside of the sphere of action of "evasion cones") and in the P-ray belt must be practically the same.

The present author estimates that the first hypothesis is correct and more natural, and that the second one must be rejected according to a series of considerations. In the following we shall enumerate the respective arguments.

a) The second hypothesis — that of the "evasion cone" — appeared in connection with the necessity of interpreting certain results of the statistical analysis of recurrent type-M geomagnetic disturbances (see [3], [4]). However, analysis of the main question, that of longi- -tudinal distribution of active region on the Sun, was omitted at the outset. At the same time if we eliminate the effect of the given factor, it will then ensue that statistics contradict the "evasion cone" hypothesis (see [5] , where additional difficulties of the considered hypothesis are discussed).

b) Let us admit for a moment, that active regions indeed"disrupt" the normal state of a more or less "uniform" solar corona. We would then have to expect that in the years of solar activity maximum, when the number of active regions and their power reach a maximum, the corona should be particularly weak in the near-equatorial belt, in which we also include, as pointed out earlier, the active regions' zone. At the same time we are aware of the fact that the opposite takes place in reality. It is well known that the "maximum" corona is indeed characterized by a relative spherical symmetry: brightness of the corona and the presence in it of radial systems — all this is nearly independent from the heliographic latitude.

c) As to the question that the general shape of the corona is in no way regulated by active regions but by specific macroscopic characteristics of Sun (see above), it is corroborated by the fact that the polar corona has quite specific characteristics, and it differs from both, the corona of the near-equatorial belt and that of the P-ray belt.

d) It is essential that the decreased brightness of intermediate corona's near-equatorial belt takes place entirely independently from the presence of active regions on or near the limb! For this points directly to the fact that active regions do not play any significant part in that problem. It must also be added that the decreased brightness in the "intermediate-type" corona takes also place for the equatorial belt itself (to $\pm 5^{o}$ from the equator). At the same time, active regions are observed at the equator relatively quite seldom.

e) Finally, it must be borne in mind , and this may apparently be the strongest argument, that contrary to the "evasion cone" hypothesis, solar corona is most dense precisely above the active regions by comparison with other radial structures (see part 4 of the present paper).

Thus, all the enumerated arguments stand against the second hypothesis and uphold the first one. In other words, there is basis to consider that the general form of the corona is indeed determined by certain macroscopic characteristics of the Sun, such as its total magnetic field (conditions for coronal structure stability vs a given field configuration), rotation of the Sun etc. On the other hand, the properties of some of these characteristics must vary with the solar cycle phase. Thus for example, the general character of the latitude distribution of the direction and intensity of magnetic fields etc., must vary. Therefore, one may expect that these cyclical variations of Sun's macroscopic characteristics must indeed determine the variations of the general form of the corona with the cycle phase. It must be added that in the years of solar activity maximum radial structures above the numerous active regions may play an important part in the brightness increase of corona's near-equatorial belt (see part 4 of this paper).

To conclude the given question, the following must be noted. Certain authors consider that the cyclical evolution of coronal forms is determined by the cyclical course of the latitude distribution of prominences. However, this is not so. We have shown above, that in the interrelationship between prominences and the corona, the latter is the primary element, though prominences may too serve as a certain indicator of the presence above them of radial structures.

3. In the present section we shall especially discuss certain characteristics of P-rays. The considerations based upon the presence of a rather clear link between the "quiescent" filaments and P-rays lead to the conclusion that P-rays have at least in their lower part, a leaf-like shape and they accompany the filaments they engulf along all their length. However, a coronal P-ray cannot be a three-dimensional copy of a filament, as this has been considered in [6]. In reality, a quiescent prominence, situated at the base of the P-ray, is characterized by a relatively small height, not exceeding 100,000—120,000 km. At the same time, the exceptionally extended P-rays have in their upper parts an entirely different structure. In particular, there is every foundation to consider that the narrowing of a P-ray at a great distance from the photosphere takes place in all directions perpendicular to the ray's axis.

It is very well known indeed, that most of the sufficiently long filaments are oriented nearly parallel to the equator. However, a fairly large number of them (in the absolute sense) are oriented at a great angle to the equator, sometimes up to 90° (see for example Fig. 3 and 4 of reference [7]). But if then the P-ray had a leaf-like shape along the whole of its axis, with a "width" of the leaf equal that of filament length (considering the "width" along a direction parallel to the filament), we should have observed quite often broad "shovel-like" rays even at great distances from the Sun (in eclipse photographs). In reality this is not so. As a rule, P-rays have a shape of long "sticks" (see for example Fig.1 in reference [8]). In other words, it must be considered that all the endings of P-rays have at great distances from the Sun an approximately cylindrical shape, while judging from eclipse photographs, the "diameter" of each such cylinder is of the order of 100,000 — 200,000 km. Let us note, that the here examined extended "cylindrical" endings of P-rays constitute the normal structure of every P-ray. Even in such a "classical" corona of the minimum epoch as that of the solar eclipse of June 30, 1954, these endings were clearly outlined (see ref. [9]).

Let us discuss still certain other properties of the lower parts of P-rays, i.e. "helmets". It is well known that clear spots are observed on the negative in the arc system above the prominence, somehow suggesting "swept out" spaces. This fact, just as the presence of the indicated arc systems itself, has been interpreted by a series of authors as a result of prominence's "explosion" (see ref. [1], pp.178-179). However, all this is incorrect. As was earlier pointed out, (section 1), quiescent prominences (in a very relative sense) appear as a result of coronal gases' condensation, and not as a result of explosive ejection of chromospheric gases. The appearance of "swept out" spaces is precisely the consequence of such condensation (see [2] p.245). At the same time gas velocities in quiescent prominences are either absent or directed downward (see for example the description of type-ANd-prominences in ref. [10])*. The fact itself of coronal gases' condensation in the prominences, and the ensuing rest of the condensed gases or their downward flow, attest to the fact that the notable systematic outflows of coronal gases in the helmet are of very little probability. Such flows would indeed contradict the very same (relatively slow) process of corona condensation. But naturally, at the same time some motions take place in the ray, since the ray itself has a solar origin. Apparently, such motions take place mainly at the very outset, at time of P-ray appearance. Later these flows attenuate, and as a result, favorable conditions appear for the condensation processes of coronal gases and prominences.

Let us examine now a very important question — the full extent of P-rays along their axis. There are a great number of arguments in favor of the fact that, in spite of the great extent of P-rays, they do not stretch to distances comparable with the distance Earth-Sun, but even if they do so, it is in a very attenuated form. It is most likely that their total extent along the axis does not exceed $30R_{\odot} - 50R_{\odot}$ Thus, according to [9]

* The same fact was kindly confirmed to me in the private letter by Dr. Dunn of Sacramento Peak Observatory, Calif., and already based upon significantly more complete observation material.

the extended equatorial parts of the corona of the 30 June 1954 eclipse were composed of several P-rays. At the same time the quantitative analysis of that eclipse, observed from a great height has shown 11 , that the electron density gradient, also in the equatorial region, showed a jump in the region R $\approx$ 30R $_{\odot}$ counting from the Sun (see Fig. 7 of [11]). It is highly probable that this jump corresponded precisely to the ends of P-rays. Any other possible explanations of that fact are quite improbable. In fact, the latest investigations [12], [13], [14] have shown that electron densities of the interplanetary medium are significantly lower at greater distances form the Sun than earlier assumed. Therefore, it is almost obvious that the jump in the electron density gradient corresponded to the transition from the corona itself to dust particles responsible for the zodiacal light phenomenon.

In connection with the further arguments in regard to the above-indicated general assertion it is necessary to make the following remarks: On the basis of a series of facts, one may estimate that at sifficiently great distances from the Sun, comparable with the distance Sun-Earth, the density of gases in coronal rays (provided they really stretch to the terrestrial orbit) must be quite low, relatively speaking. That is why, using the standard radioastronomical and optical methods, and making observations from the ground, the detection near it of the coronal ray constitutes a very difficult problem indeed. That is why also data on the Earth's magnetic field are generally utilized as an indicator that must point to the presence (or absence) near the Earth of a coronal ray identifiable with the corpuscular stream. In particular, and contrary to the data on polar aurorae and ionosphere, geomagnetic disturbances appear to be the most direct indicator of the inflow of corpuscules near the Earth. Besides, this indicator is the most sensitive. That is why we shall refer in the subsequent argumentation to the results of comparison of solar and geomagnetic data.

Certain authors, (see for example [15], [16]), trying to prove that M-disturbances are induced by P-rays, and that consequently P-rays reach the terrestrial orbit, make use of data on quiescent prominences or filaments. It is however questionable that such a method can supply any tangible results. In reality, it is well known that M-disturbances are characterized by a great stability. At the same time it is contradiction with the character of filament behavior. (The latter are observed on the disk of the Sun, and that is why it is much easier to track their behavior than that of prominences at the disk's limb). Although every filament is usually observed in the course of several solar convolutions (three as an average), the general form of the filament and particularly the position of its endings are nevertheless quite often subject to quite strong variations. At times the filament may even temporarily disappear, it may break in parts, merge with other filaments etc. Those filaments which appear and exist within the most active region show a particular instability. In connection with the above-said, all these manifestations of instability of filaments are to a significant extent the result of time-variable conditions of coronal gas condensation and of filament disintegration. Therefore, there is no sense to have the recourse to prominces and filaments in the attempt to interpret the problems set up in the present paper. It is thus not surprising that all the comparisons of filaments with M-disturbances carried out failed to contribute any specific results. Such incidently was the conclusion reached by Hansen [17] , having studied nine of the most steady geomagnetic sequences from 1918 theough 1944. (The direct comparisons of filaments and M-disturbances, carried out by the present author for theses 9 sequences, fully corroborated Hansen's conclusions). The same follows from a careful examination of the graphs by Bednárova 18 19 , although the author himself holds to the opposite opinion. As to the conclusions of works [15] and [16] , they are based upon a too limited material.

We may still add to the above-said, that filaments do not play any part in the geoactivity conditioned by the active regions of the Sun. (see Fig.4 in reference 20).

Unfortunately, unilateral comparisons of M-disturbances with the results of direct eclipse observations are impossible. In fact, the examination of the Meudon 27-day maps of solar chromospheric activity shows, that the general extent of filaments in the zones of quiescent prominences sometime reaches to 200—300°. As the most striking examples we may point to periods included between the revolutions 1211—1229, 1255—1265, and to a number of other cases. This general tendency is well represented in the corresponding "composite" maps of reference 7 . In the presence of the already discussed connection between P-rays and filaments, all this means that P-rays, and in any case their lower parts— helmets— must also follow the just discussed rules. In other words, in steady latitude zones of filaments helmets must quite often follow one another around the Sun (along a parallel), and nearly continuously.

Similarly, we must observe in an enormous number of cases a mutual superimposition (projection on the celestial sphere) of several and at times numerous helmets and rays. There is no possibility of outlining separate helmets only on the basis of usual eclipse observations, for during eclipses we only register a total number of free electrons along the visual ray. This conclusion also follows from eclipse photographs (and drawings made after photographs). This photographs show indeed that quite often, and particularly in the zone of maximum P-ray encounter, there takes place a mutual superimposition along the visual ray of several P-rays. Thus, for example, a photometric cross-section of such a "composite" P-ray across its axis points to the presence of separate, sufficiently sharp "jumps" in brightness, attesting to the fact that we register not one, but several rays, with axes making various angles relative to the pictorial plane. To this we still must add that generally in the main zones of quiescent filament disposition we nearly always see the P-rays in the eclipse photographs.!

It follows from the above-said, that no matter what superposition of coronal rays with geomagnetic disturbances, its application on photographs makes no sense at all. As to the establishment on that basis of corpuscules' time lag, it is still more senseless. To illustrate this we may for example indicate that certain authors estimated the presence of a link between the large eastern ray of the 25 Feb.1952 eclipse amd the corresponding geomagnetic disturbances as well established. However, there are serious objection to such a conclusion (see [22] , p.78 and also 21 p.79).

Taking the above considerations into account, we shall extend our argumentation by linking it with the data resulting from the analysis of geomagnetic disturbances. (Only the fifth argument e) has a character indepedent from the geomagnetism). This has already been made to a significant extent in previous works by the author [22] and [23], and we shall only repeat here the brief basic content of the respective considerations.

a) The recurrent geomagnetic disturbances of the M-type are characterized by a clearly-expressed seasonal pattern, with two equinoctial maxima. The most natural explanation of this is that corpuscular streams from the Sun, creating M-disturbances, are nearly radial. Other explanations are here highly improbable. Thus for instance the seasonal pattern of M-disturbances cannot be the result of the effect of any specifically geophysical factors, for the seasonal course reveals not only the intensity but also the number of M-disturbances. Besides, it must be borne in mind that M-disturances are rather often observed (because of separate disruptions of streams' radiality) during summer and winter solstices ($B_o \approx 0^o$). At the same time, the intensity of such disturbances is sometimes quite high (see for example the classical continuity of disturbances from June 1943 to March 1944). The given fact points directly to the fact that strictly geophysical conditions do not play any part in the seasonal course of M-disturbances, and that the examined seasonal variations are entirely determined by corpuscular streams' geometry.

The indicated radiality of corpuscular streams creating the M-disturbances must have an entirely specific character: radial streams must egress from regions situated in any case near the equator, and yet they have to avoid the equatorial zone itself. (These requirements are satisfied by the active regions for the phase of solar activity, when the seasonal character of M-disturbances is most clearly revealed). However, P-rays do not satisfy these requirements (see pp. 19 and 29 of ref. [22]). In particular, the part of M-disturbances increases from the maximum to the minimum of solar activity, while at the same time the P-rays' deflections from radiality also increase in that direction (refer to the drawing 82 of [1]). Besides, P-rays usually have inclinations (toward the radial direction) quite different from one another for an identical moment of time, i.e. in the corona of the same eclipse (see pp. 29—30 of ref. [22] , and also Table 26 of ref. [1]), so that there can be no question of radiality. It is quite true though, that at great distances from the Sun the "cylindrical" endings of P-rays may be viewed with a known approximation as radial. However, this is in no way related to the explanation of the seasonal pattern of M-disturbances. Finally, even the first of the indicated requirements is not satisfied for P-rays, say the mid-latitude of quiescent filaments linked with the active regions, is by about 10^{o} greater than the middle latitude of the active regions themselves. In other words, the bases of P-rays (helmets) are disposed sufficiently far from the equator in an overwhelming number of cases.

b) The recurrence of M-disturbances and their stability in general undergo a sharp variation (attenuation) immediately after the solar activity minimum. This even has a character of a jump (see pp. 20 Fig.12 and p.24 Fig.16 of [22]). In other words, sharp variations take place in the geometry of the type M-corpuscular streams in a very brief time period. At the same time, nothing of that sort is observed relative to P-rays. The variations in the shape of the corona during the considered time period usually take place smoothly, as shown for example by eclipses of 21 August 1914, 24 January 1925 and 9 July 1945. All these eclispes were observed after solar activity minima, when the recurrence of disturbances was already absent, but the form of the corona (characterized to a greater degree by P-ray geometry) practically corresponded to the corona minimum. For a more detailed discussion of this question, please refer to pp. 30—31 of [22]).

c) The mean duration of a single M-disturbance is of 4-5 days and it even reaches 10 to 12 days in a series of cases, while during all this period the Earth is indeed in the midst of the corpuscular stream [24] . Thereby, the "width" of an average corpuscular beam at distance of the Earth measured along the latter's orbit, constitutes near 150,000,000 km. At the same time the diameter of the "cylindrical" endings of P-rays constitutes near 100000 — 200000 km (see above). All this means that we have here a divergence of at least three orders.

d) As was already pointed out earlier, in the photographs of the eclipse of 30 June 1954 P-rays revealed a quite strong concentration in the equatorial plane. At the same time and inspite of great brightness of the corona at taat time, the geomagnetic activity did not indicate any maximum corresponding to the moment when the Earth was in the solar equatorial plane (beginning of June, $B_o = 0^o$). On the contrary, the geomagnetic activity revealed two usual equinoctial maxima that corresponded to the "remains" of earlier-existing sources of M-disturbances on the Sun (see this at further length in ref. [23]). It is quite obvious that this is a general case, applicable to all other minima of solar activity.

e) The last radioastronomical observations completed by Slee [26] show directly, that sufficiently stretched coronal formations (streamers) are observed only above the equatorial regions of the Sun. They are not observed in the high-latitude regions where the main part must be played by P-rays. Furthermore, these investigations show that the indicated formations are closely linked with the active regions, as this is in complete agreement with the results obtained by the present author [20].

Therefore, all the considered arguments do indeed speak of the fact that P-ray endings do not extend to the terrestrial orbit, and if they do so, it is in a very attenuated form.

In conclusion of this section we shall make some comments in regard to Waldemeier work [26] in which the author comes to the conclusion on the basis of the study he made of an eruptive prominence, that the latter's motion took place along the P-ray, and was determined by the "solar wind", and that this defines the P-rays as intense stationary gas flows. However, it is impossible to rally to the Waldemeier conclusion. It is indeed well known that eruptive prominences are quite rare and random phenomena, and it is clear that as such they have no reltionship with such exclusively steady and frequent sequences as the M-disturbed are. Nor had the prominence explosion observed by Waldemeier any connection with the "solar wind" and to gas flow inside the streamers above the prominences. Had these flows been somewhat substantial, one would have been led to expect, as a rule, ascending flows in quiescent prominences. But we have seen at the same time that the opposite is observed. It is clear that the forces having ejected the Waldemeier's prominence were of electromagnetic origin, by which prominence motion is generally defined. In favor of this assertion we have the fact, that usually the motions of separate parts of a prominence during the "explosion of its eruptive form are not only directed upward but also sideways. This also contradicts the pattern of gas flow along the upward-narrowing P-ray (!). In other words, it must be considered that the coincidence or overlapping of the trajectory of the Waldemeier prominence with the general contour of the corresponding coronal streamer (P-ray) along the axis was <u>entirely fortuitious</u>. Finally, one must bear in mind that no additional arguments on the corpuscular nature of P-rays is included in Waldemeier's work (except the introduction of the "solar wind" hypothesis). Thus all the above objections apply to it also.

The second part of this work*) will deal with coronal rays above the active regions, and in conclusion we shall discuss the question of the agreement of optical eclipse observations with other conclusions of coronal observations.

****** THE END ******

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